AD641017

SAM-TR-66-80

DESIGN AND DEVELOPMENT OF AN AUTOMATIC INDIRECT BLOOD PRESSURE MONITORING DEVICE

JAMES E. ALLRED, B.S.E.E.
JACK B. JOHNSON, M.S.E.E.

CLEARINGHOUSE
FOR FEDERAL SCIENTIFIC AND
TECHNICAL INFORMATION
Hardcopy Microfiche
$1.00 0.50 14 ma
ARCHIVE COPY

September 1966

DDC
NOV 1 1966
A

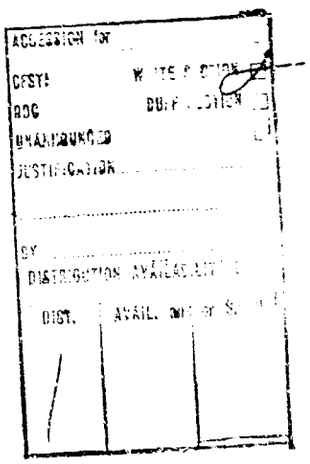
BEST
AVAILABLE COPY

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas

Qualified requesters may obtain copies of this report from DDC. Orders will be expedited if placed through the librarian or other person designated to request documents from DDC.

When U. S. Government drawings, specifications, or other data are used for any purpose other than a definitely related government procurement operation, the government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Distribution of this document is unlimited.



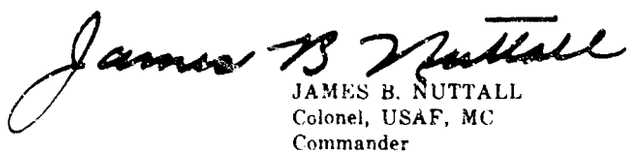
DESIGN AND DEVELOPMENT OF AN AUTOMATIC INDIRECT BLOOD PRESSURE MONITORING DEVICE

JAMES E. ALLRED, B.S.E.E.
JACK B. JOHNSON, M.S.E.E.

FOREWORD

This report was prepared by the Biomedical Engineering Branch, USAF School of Aerospace Medicine, under task No. 632001. The work was accomplished between February 1964 and December 1964. The paper was submitted for publication on 27 June 1966.

This report has been reviewed and is approved.



JAMES B. NUTTALL
Colonel, USAF, MC
Commander

ABSTRACT

The design of an automatic electronic blood pressure recording device is described. This device, which applies pressure only slightly higher than the systolic pressure of the subject, is programed to record the Korotkoff sounds while the occlusion cuff is being inflated. The system may be programed to monitor blood pressure at any predetermined rate from intervals of one minute to several minutes, or it may be initiated manually.

Proper design of circuitry for maximum signal-to-noise ratio required a knowledge of the frequency range of the complex Korotkoff sound waveform. This information was obtained by recording the K sounds from four subjects and analyzing the waveforms for energy content vs. frequency. These data are also presented.

DESIGN AND DEVELOPMENT OF AN AUTOMATIC INDIRECT BLOOD PRESSURE MONITORING DEVICE

I. INTRODUCTION

Many automatic blood pressure recording devices utilized on human subjects operate by inflation of an occlusion cuff to some predetermined pressure level which is then slowly released until the systolic and diastolic pressures can be recorded. This predetermined pressure level has to be quite high (say, 250 mm. Hg) to cover the wide range of blood pressures encountered, but in some cases during heavy exercise this pressure is not high enough to record systolic pressures. High monitoring rates (one per minute, for example) over long periods of time produce considerable discomfort to the subject. Another apparent disadvantage of some of these systems is that there is a great amount of movement artifacts during exercise of the subject.

The design goal of this project was to provide an automatic blood pressure device which would (1) provide minimal discomfort, (2) provide a wide dynamic pressure range, and (3) reduce movement artifacts under dynamic stress testing.

II. SYSTEM DESIGN AND OPERATION

The measurement cycle of the system shown in figure 1 (also shown in block diagram form in figure 2) is started in the automatic mode by the one-minute timer or in the manual mode by pressing the manual reset switch. When either of these events occurs, the 3-way air valve allows pressure to be applied to the cuff and pressure transducer at a rate determined by the flow valve. As the cuff is being inflated, the Korotkoff sounds are obtained from a recording microphone and are superimposed on the voltage from the pressure transducer which is proportional to the applied pressure. The voltage from the pressure transducer is also applied to the pressure level detector which determines the pressure at which the occlusion cuff will deflate. The K sounds and cuff pressure outputs (0 to 2.5 v. max.) have been designed to be compatible with most FM magnetic tape recorders.

Amplifier and filter

The differential amplifier in figure 1, which was designed to accommodate long input connection leads, has a common mode rejection of 65 dB, an overall voltage gain of 70 dB, and an equivalent input noise level of approximately 1 μv. The amplifier is followed by four stages of low-pass active filtering designed for a total slope of 48 dB/octave with a rolloff beginning at 40 Hz. The overall frequency response of the amplifier and filter, as shown in figure 3, provides an adequate range for the Korotkoff sounds and reduces the level of 60 Hz to -9 dB relative to the bandpass. The filter was designed to have a sufficiently narrow bandpass to reduce noise from movement artifacts but not so narrow as to produce filter ringing. Reasons for using this bandpass will be discussed in section III.

Pressure transducer

The pressure transducer employed requires a differential supply voltage and provides an output from 0 to 5 volts d.c. for pressures ranging from 0 to 300 mm. Hg; however, any pressure transducer which could produce a linear output for the pressure range given would be suitable. The output of this transducer is added to the amplified and filtered Korotkoff sounds at the summing amplifier.

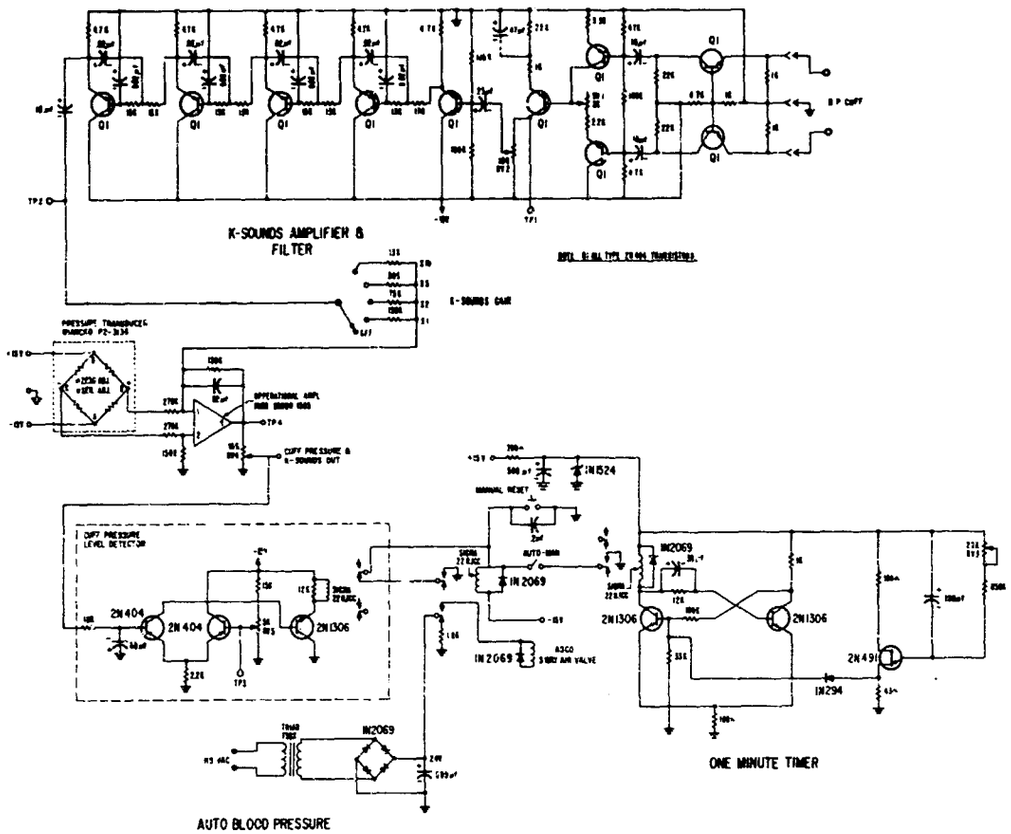


FIGURE 1

Schematic diagram of amplifier and filter.

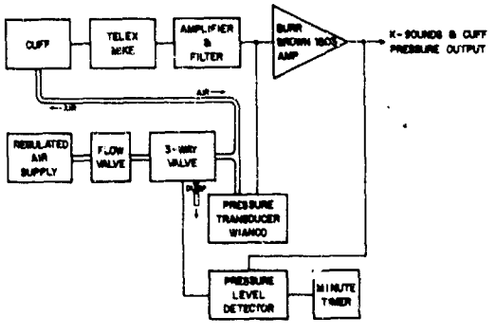


FIGURE 2

Automatic blood pressure system block diagram.

Summing amplifier

The summing amplifier, a d.c. operational amplifier, provides the combined cuff pressure and Korotkoff sounds at a low-output impedance (200 ohms). The output is adjustable through RV4 to provide the desired level for recording. The output is also fed to the pressure-level detector.

Pressure level detector

During system operation the pressure level detector receives a voltage from the summing amplifier (Burr-Brown model 1503) which is proportional to the pressure applied to the cuff. Variable resistor RV5 is calibrated against an

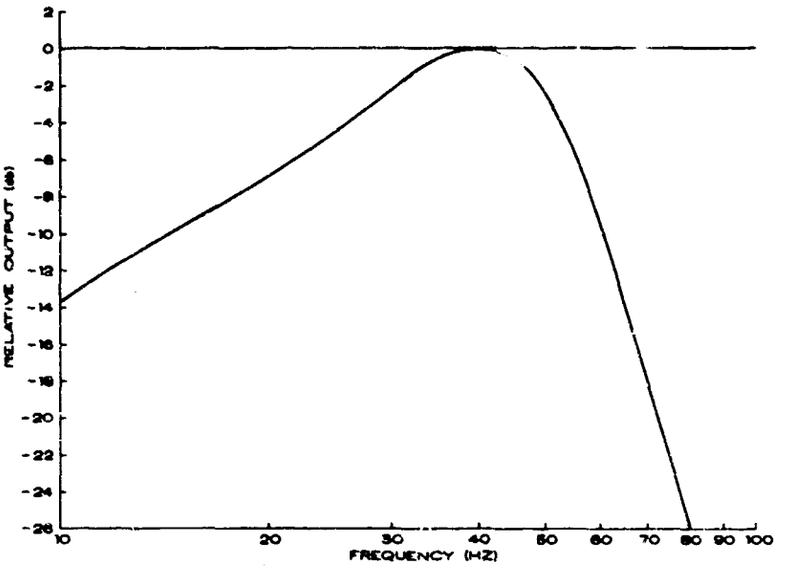


FIGURE 3

Overall response curve for amplifier and filter.

aneroid or mercury manometer from 0 to 300 mm. Hg. When the pressure applied to the cuff reaches the pressure setting on RV5, the level detector releases the voltage applied to the 3-way valve, and the pressure cuff is deflated. Adjustment of RV5 allows the operator to make an initial setting of the maximum pressure applied to the occlusion cuff. This is normally adjusted to 5 to 10 mm. Hg above the systolic pressure of the subject and need not be readjusted for any one subject.

Timing device

The timing device utilizes a unijunction oscillator and Schmitt trigger to provide a one-minute output which recycles the system operation when in the automatic mode. The timing accuracy is approximately one second/hour and can be adjusted at RV3. Although a one-minute timer is used to generate the automatic cycle of the blood pressure device, any convenient timer (for example, one per hour) may be used.

III. EXPERIMENTS AND RESULTS

Korotkoff sound frequency spectrum

The design of the circuitry for the maximum signal-to-noise ratio required determination of the frequency content of the complex Korotkoff sound waveform (K sounds), which was accomplished in the following manner. A recording microphone (Telex model RTX-04) was first attached to the diaphragm portion of a stethoscope as shown in figure 4 and calibrated in an anechoic chamber using the test setup of figure 5. Korotkoff sounds were then obtained from four subjects by placing the calibrated microphone under an occlusion cuff over the brachial artery (see fig. 6) and recording the K sounds on a Dacord FM tape recorder. The recorded K sounds obtained were then analyzed for frequency content using the test setup of figure 7.

Korotkoff sound tests and results

Data obtained from microphone calibration (see table I) are shown as a corrected microphone and amplifier response which represents

FIGURE 4

Photograph of microphone attached to stethoscope.

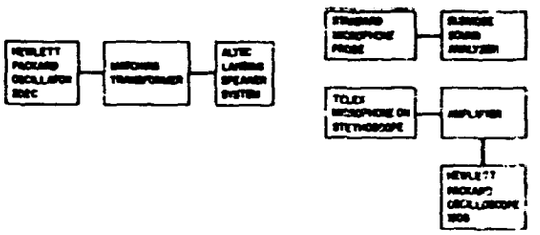


FIGURE 5

Instrumentation test setup for microphone calibration.

A

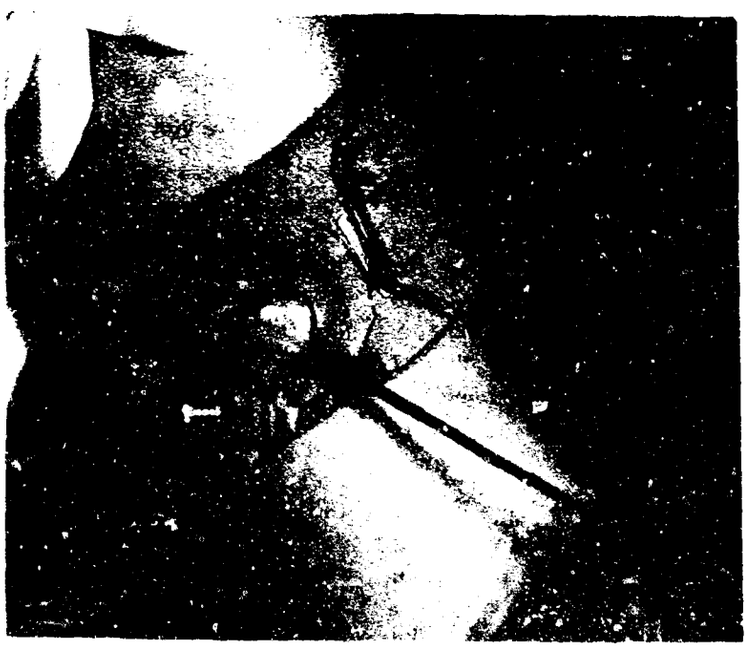


FIGURE 6

A. *Method for attaching microphone to holding cuff.*
B. *Attaching microphone to the subject.*

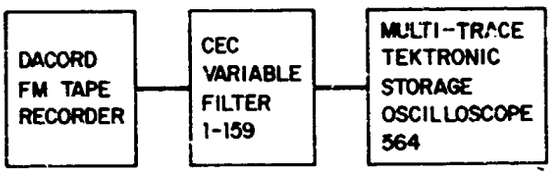


FIGURE 7

Test setup for analyzing frequency content of K sounds.

a "flat" response related to the laboratory standard microphone and a Rudmose sound analyzer. Accurate data below 40 Hz were not obtainable owing to signal distortion from the Telex microphone. The response of the recording microphone is shown in figure 8.

Tabulated data of the tests conducted on the K sounds for frequency content shown in table II have been corrected to the microphone response curve of figure 8. Each column gives the relative K sound energy spectrum vs. frequency for the four subjects. Since there is little variation of K sound energy level between subjects, an average column for the four subjects is also shown in table II and is presented graphically in figure 9.

TABLE I

*Telex microphone and amplifier calibration**

Frequency (Hz)	Standard microphone and Rudmose sound analyzer output	Amplifier and Telex microphone output	Corrected amplifier and microphone response
		(decibels)	
40	−1.4	−24.4	23
45	−1.15	−20.0	18.85
50	−1.25	−18.06	16.81
55	−0.98	−12.0	11.02
60	−0.65	− 7.96	7.31
65	−0.40	− 6.0	5.6
70	− 0.29	− 3.1	2.81
75	−0.50	− 5.2	4.7
80	−0.31	− 3.74	3.43
85	−0.10	− 1.94	1.84
90	0.02	0	−0.02
95	0.03	0	−0.03
100	0	0	0

*All measurements are referenced to 100 Hz.

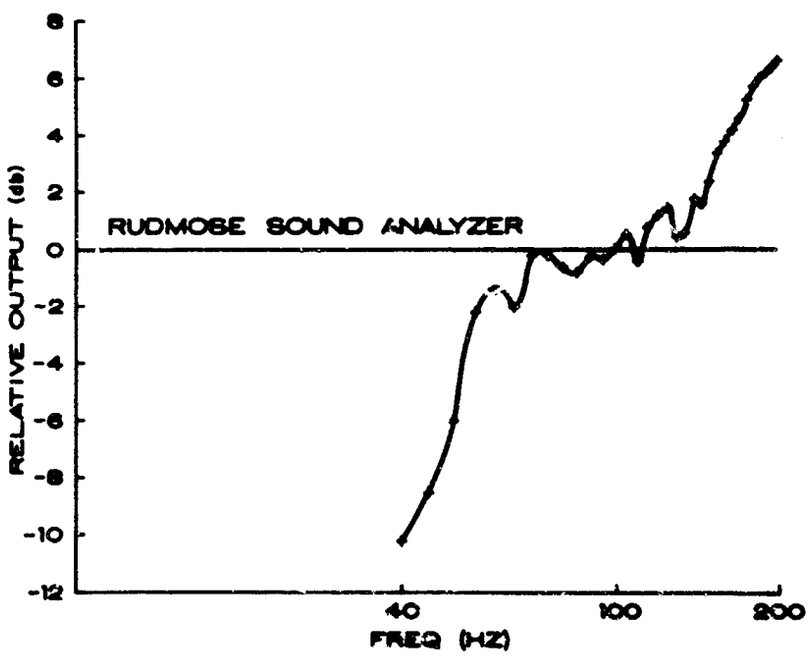


FIGURE 8

Composite calibration curves for Telex microphone and amplifier.

TABLE II

*Corrected Korotkoff sound energy level**

Frequency (Hz)	Corrected value	K_1	K_2	K_3	K_4	K Av.
	(decibels)					
40	23	35.2	35	33.4	32.85	34.2
45	18.85	31	28.8	31.2	31.35	30.5
50	16.8	26.8	24.4	31.2	31.0	28.4
55	11.02	25.2	21.0	27.7	25.5	24.8
60	7.31	23.3	20.6	21.7	21.1	21.6
65	5.6	20.4	18.8	20.0	17.6	19.2
70	2.8	14.8	12.8	14.6	14.3	14.1
75	4.7	14.7	12.3	13.5	14.5	13.7
80	3.43	10.6	7.43	10.38	13.23	10.4
85	1.84	7.04	5.4	6.29	8.59	6.8
90	— 0.02	4.2	3.2	1.78	5.5	3.7
95	— 0.03	2.2	2.2	1.0	3.2	2.1
100	0	0	0	0	0	0

*All measurements are referenced to 100 Hz.

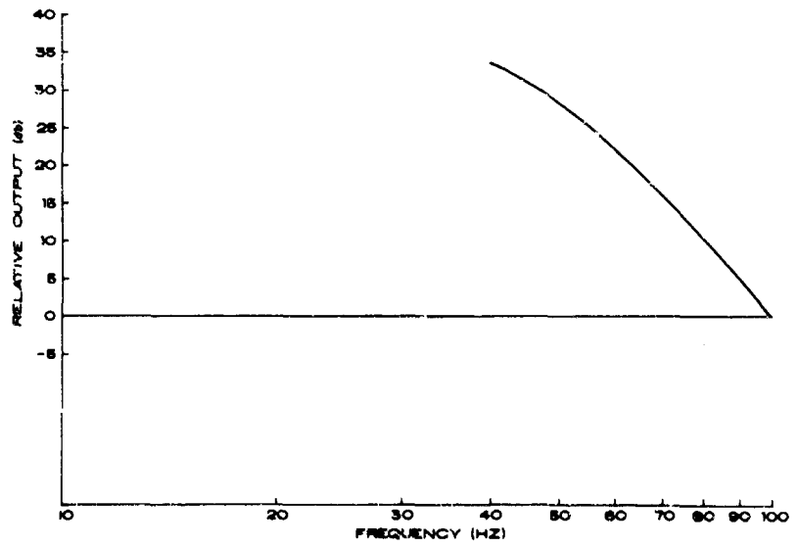


FIGURE 9

Average Korotkoff energy level vs. frequency.

Data are not shown above 120 Hz for obvious reasons. Tests were actually conducted up to 400 Hz, but no significant amount of signal was present at these frequencies. It is unfortunate that the recording microphone did not respond adequately below 40 Hz; however, it may reasonably be concluded upon inspection of figure 9 that the most significant portion of energy contained in the Korotkoff sounds is below 55 Hz.

Since the objective of this experimentation was to produce circuitry which would provide maximum signal-to-noise ratio and not to faithfully reproduce the Korotkoff sound waveform, no attempt was made to differentiate between the diastolic and systolic frequency spectrums. Experiments conducted by Rauterkus et al.[1] coincide with the conclusion of the report—i.e., the most significant energy level is below 55 Hz. These experiments were performed by conducting a Fourier analysis on the complex Korotkoff waveforms of several subjects.

IV. DISCUSSION

The automatic electronic blood pressure monitoring device described is presently being used in a bed rest–exercise study at the School of Aerospace Medicine. An additional timer was employed to provide a measurement every 15 minutes. After the subject has been instrumented and the maximum pressure level set, the subject's blood pressure can be recorded once every 15 minutes while unattended. A modified version of this device was also successfully employed in a dynamic stress testing area where it was required to monitor and record the blood pressure of the subject each minute while exercising. A graphical write-out of a typical blood pressure measurement is shown in figure 10.

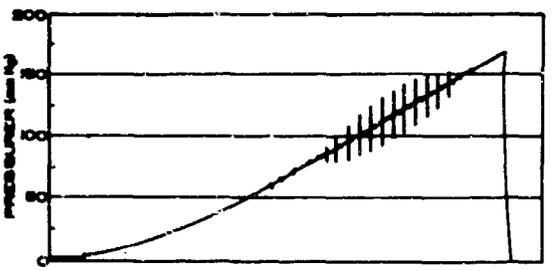


FIGURE 10

Typical blood pressure measurement.

It is felt that this initial study in electronic blood pressure monitoring and the developed prototypes should form the basis for further research and development in indirect blood pressure monitoring.

[1]Rauterkus, T., J. F. Feltz, and J. W. Fickes. Frequency analysis of Korotkov blood pressure sounds using the Fourier transform. SAM-TR-66-8, Feb. 1966.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b GROUP

3. REPORT TITLE

DESIGN AND DEVELOPMENT OF AN AUTOMATIC INDIRECT BLOOD PRESSURE MONITORING DEVICE

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Feb. - Dec. 1964

5. AUTHOR(S) *(Last name, first name, initial)*
Allred, James E.
Johnson, Jack B.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
Sept. 1966	7	1

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. 6320	SAM-TR-66-80
c. Task No. 632001	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	USAF School of Aerospace Medicine Aerospace Medical Division (AFSC) Brooks Air Force Base, Texas

13. ABSTRACT

The design of an automatic electronic blood pressure recording device is described. This device, which applies pressure only slightly higher than the systolic pressure of the subject, is programed to record the Korotkoff sounds while the occlusion cuff is being inflated. The system may be programed to monitor blood pressure at any predetermined rate from intervals of one minute to several minutes, or it may be initiated manually.

Proper design of circuitry for maximum signal-to-noise ratio required a knowledge of the frequency range of the complex Korotkoff sound waveform. This information was obtained by recording the K sounds from four subjects and analyzing the waveforms for energy content vs. frequency. These data are also presented.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Bioinstrumentation						
Physiology						
Korotkoff blood pressure sounds						
Frequency analysis (blood pressure sounds)						
Automatic blood pressure monitor						
Monitoring under exercise						
Blood pressure monitoring						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14 KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

GPO 886-551